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NOISE REDUCTION AS AFFECTED BY THE EXTENT AND DISTRIBUTION
OF ACOUSTIC TREATMENT IN A TURBOFAN ENGINE INLET

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Abstract

An inlet noise suppressor for a TF-34 engine designed to have three acoustically treated rings was tested with several different ring arrangements. The configurations included: all three rings; two outer rings; single outer ring; single intermediate ring, and finally no rings. It was expected that as rings were removed, the acoustic performance would be degraded considerably. While a degradation occurred, it was not as large as predictions indicated. In fact, the prediction showed good agreement with the data only for the full-ring inlet configuration. The under-predictions which occurred with ring removal were believed a result of ignoring the presence of spinning modes which are known to damp more rapidly in cylindrical ducts than would be predicted by least attenuated mode or plane wave analysis.

Introduction

Noise reduction concepts for STOL (short take-off and landing) and short haul aircraft were studied on a full scale TF-34 engine as part of an on-going STOL technology program at the Lewis Research Center. This report is concerned specifically with noise radiated from the engine inlet. Noise reduction characteristics of the acoustically treated three-ring inlet on the TF-34 engine were discussed in reference 1. Designers anticipated that acoustically treated rings would be necessary in the engine inlets in order to meet the future requirements of more stringent noise reduction. However, some recent experimental evidence[2,3] indicates that acoustically treated inlets without rings (called open inlets) may reduce noise more effectively than early theories predict. A recent analysis[4] corroborates such a possibility. Several TF-34 engine tests explored this behavior of noise suppression in open inlets. To achieve large noise reduction without resorting to acoustically treated rings is a highly desirable goal. An open inlet acoustic suppressor has the following advantages over a suppressor with rings: less complicated structure, less weight, lower installation expense, lower aerodynamic losses, and greater ease of access to rotating machinery.

To evaluate noise reduction effects, several configurations of the inlet suppressor were tested. As designed, the liner had three treated rings.[1] Some test results of the three ring inlet configuration are repeated from reference 1, for comparison purposes. Variations from the three ring inlet represent departures from the design condition. Therefore, it might be expected that a specifically designed three-ring configuration would probably perform better than the inlet configuration operating off-design with one or more rings removed. In particular, the open inlet case with all of the rings removed, is a significant departure from the originally designed suppressor.

The inlet suppressor configurations tested included several variations of the amount of active acoustic wall treatment in the open inlet case. In addition, different ring emplacements were tested, from three rings to one ring. For all cases tested, the engine aft end noise was highly suppressed with a long exhaust muffler.

The far field measured results are presented here in several forms which have become more or less standard format for engine acoustic data, e.g., perceived noise levels, etc. In addition to the presentation of measured results, a brief comparison is made between measured and predicted suppressions.

Apparatus and Procedure

Engine

The TF-34 engine and its ground test nacelle for this test series were described in references 1, 5 and 6. Some basic design and measured operating parameters for the engine are listed in Table 1. Figure 1 shows a photograph of the engine on the test stand with its tail pipe extension and 18.3 m (60 ft) long acoustically treated aft muffler. The muffler was lined with a 45.7 cm (18 in.) deep woven bulk absorber (which was contained by a steel perforate with a large open area). This muffler eliminated the engine aft noise from being a consideration at the inlet hemisphere measurement stations. Because the flow area of the muffler was larger than the engine exhaust area, the jet speed decayed significantly within the muffler and reduced the amount of jet noise generation outside of the device.

The engine and noise suppression system were tested at several fan speeds from 5100 to 6900 rpm. The results presented here are for 5100 and 6200 rpm, chosen as representative of low and high speed performance. At 6200 rpm the noise spectra have a significant buzz saw or multiple pure tone (MPT) content.

Acoustic Treatment

The inlet acoustic treatment is 12 cm (0.480 in.) deep honeycomb material covered with 6.8% open area perforated face sheet. The design of the inlet acoustic treatment was discussed in reference 1. For these tests, the acoustic treatment was arranged in several configurations which departed from the original design condition.

The original design included three treated rings in the inlet as shown in figure 2. The purpose of installing these rings was to reduce the passage height between treated surfaces while simultaneously increasing the individual treated passage length-to-height ratio. The removal of any of these rings should be expected to change both the amount of acoustic suppression and probably the frequency of the peak suppression. The total acoustically treated area in figure 2 was 12 m² (129 ft²).

The first alteration of the inlet suppressor was the removal of all of the rings, as shown in figure 3(a). The only acoustic treatment remaining was on the nacelle wall. This arrangement is referred to as the open, or no-ring inlet, configuration. This open inlet was tested in several configurations using different lengths of active treatment by selectively taping over the remaining axial portions of the liner starting forward and working to the fan.

In addition to the axial length variations, two other open inlet configurations were tested. These configurations were formed by the use of alternating strips of tape and active treatment parallel to the engine axis. In both of these cases, 20% of the total open inlet liner area remained active. In one case there were 55 active strips each 1.27 cm (0.5 in.) wide, and in the other were 12 active strips each 5.84 cm (2.3 in.) wide as shown on figure 3(b).

Other liner configurations tested included arrangements of treated rings, as shown in figure 4(a), (b), and (c). These were: two outer rings in place, single outer ring in place, and single intermediate ring in place. For purposes of comparison, some results with all three rings in place[1] are included here also.

In all cases in this report where attenuation spectra are presented, the baseline configuration was the open inlet with all of the treatment taped to simulate a hard nacelle.

Test Facility and Instrumentation

The engine was supported by an overhead cantilevered support arm to maintain the engine centerline at 2.7 m (9 ft) above the ground plane, (fig. 1). The ground surface was smooth concrete over most of the test site, with asphalt pavement extending beyond the microphone array.

A plan view of the site, (figure 5), shows the placement of far field microphones on a 30.5 m (100 ft) radius arc centered on the engine tail pipe. Various combinations of these microphones were tested, with placement on the ground and at the engine centerline height. The availability of data processing channels limited the total number of microphones which could be used and thus not all measurement locations could be recorded simultaneously. The results presented here for the baseline and several of the treated inlet configurations are from a set of microphone locations at the engine centerline height, with microphones at 10 degree increments on the noted arc. The results from the remaining treated configurations were from basically the same microphone array, except that the 10° and 30° microphones were omitted.

Set up for aft end noise investigations, the microphone arc was arranged assuming an aft end noise source with the center of the arc located there. For these tests the effective noise source was located at the inlet plane of the bellmouth, since the aft muffler suppressed the aft source. Accordingly, calculation of sound powers was made relative to the effective source location. Therefore the data processing computer was programmed to calculate sound pressure levels on a corrected 30.5 m (100 ft) radius arc centered on the engine inlet, and at the actual angles of the microphone

positions relative to this new center. The correction involved a mathematical translation of coordinates in which the origin was moved along the centerline of the engine from the aft end to the inlet plane. The distance of translation was 6.98 m (22.9 ft).

The readings from the 1.26 cm (0.5 in.) B&K far field microphones were processed on-line through the standard Lewis Research Center 1/3-octave band data reduction system discussed [7]. Only a few selected microphones were tape recorded. Calculations of sound levels at locations other than the measurement stations were performed consistent with the methods of reference 8. Power levels were calculated assuming an axisymmetric source and integrating the far-field sound intensity over the inlet hemisphere. Thus, no attempt was made to correct the results to free-field conditions. The ground reflection effect is a complex phenomenon dependent on frequency. On the average, however, the presence of the ground plane reflects extra energy to the microphones. Ignoring this effect therefore may produce absolute levels which are high, but it should not affect comparisons among different configurations reported here. By integrating only over the inlet hemisphere, the effect on the results of any residual noise escaping from the aft muffler is minimized.

Multiple data samples (generally two or three) were measured in the far field for most cases. Variations in the spectra from one sample to another were generally less than 1 dB.

Results and Discussion

The acoustic performance of an inlet noise suppressor was measured for several different configurations of acoustic treatment. The results from the far field acoustic measurements are presented and compared with the results for an acoustically hard open inlet baseline case.

The TF-34 engine test vehicle was run at several fan speeds in the range of 5100 to 6900 rpm. Two speeds, 5100 and 6200 rpm, were chosen for data presentation as typical of low and high speed performance for both the engine and the noise suppressor. MPT's are present at 6200 rpm and above.

The order of presentation of acoustic results is as follows: effects of treated length in an open inlet, effects of longitudinal strips of active treatment in the open inlet, and insertion effects of one to three acoustically treated rings. In the length and striping tests the variations of active acoustic treatment were achieved by taping over varying portions of the full liner.

Open Inlet Results

This section presents far field acoustic data for the inlet acoustic suppressor without rings. Perceived noise levels and noise spectra are examined for the effects of active treated length. The active surfaces started at the fan and progressed forward.

Figures 6(a) and (b) present the distribution of PNL (perceived noise level) as a function of angle along a 152.5 m (500 ft) sideline for several different lengths of active treatment, including the zero active length baseline case. The hard baseline curves for both speeds are characterized

by low levels at the rear (large) angles and peak levels at 50.1° and 61.6° for 5100 and 6200 rpm respectively. The aft levels are low, because of the very effective suppression of the noise emanating from the aft end of the engine. In general, the shapes of the curves for the treated configurations are similar to the curves for the baseline. Increasing the length of active treatment gave a regular progression of PNL reductions for most cases. However, the peak PNL angle shifts forward as the amount of active liner is increased. It is speculated that this observation may be explained in terms of the fan acoustic modes which exist and are dissipated in the inlet duct. The acoustic energy in the duct is probably distributed among a group of acoustic modes. In the presence of acoustic treatment, high order modes damp faster than the low order modes[4]. In the sound field high order modes also tend to radiate more toward the 90° position while the low order modes radiate more toward 0°. These ideas assembled together may indicate that the baseline noise directivity patterns are dominated at 50.1° and 61.6° for 5100 and 6200 rpm, respectively, by higher order modes. These higher order modes damp relatively rapidly and leave a suppressed configuration dominated by low order modes which damp more slowly and beam further forward. Of course, it should be expected that as the higher order modes are reduced by increasing amounts of treatment, the noise levels, even at 50.1° and 61.6°, would begin to be dominated by the lower order mode sound radiation.

The noise reductions at the forward quadrant in general were greater than those at the aft quadrant. The reductions of peak PNL amounted to about 8 and 9 PNdB at 5100 and 6200, respectively, for the full length open inlet suppressor. For the full three ring inlet liner[1] the corresponding reductions were 15 and 19 PNdB.

The microphone angles shown in figure 6 are not evenly spaced because the computer shifted microphone radius as explained in the section on the test facility. In addition, the 38° angle location is missing from the 37.4% soft configuration data because there was no microphone at that location for that test series.

A closer examination of the liner noise suppression effectiveness can be gained by looking at spectra of SPL (sound pressure level). It would be convenient to be able to pick the angles of peak PNL for this examination while remaining at the same physical angle in the radiation field. However, this is not possible because of the peak angle shift. Therefore the presentation is made at the peak baseline noise angle.

Figures 7(a) and (b) show the SPL spectra for 5100 and 6200 rpm. The noise levels decreased with increasing active length, over most of the noise spectrum above 500 Hz. There is a significant difference between the spectra at the two different speeds. At 5100 rpm the spectra are dominated by the blade passage tone and its harmonics. At 6200 rpm the baseline spectrum is dominated by buzz saw or MPT (multiple pure tone) noise at frequencies below 3150 Hz. A significant fact to observe is that the smallest addition of acoustic treatment resulted in a large reduction of the MPT's. The blade passage tone was only slightly reduced by the same treatment addition.

In order to examine total noise generation and reduction effects exclusive of directivity, the inlet PWL (sound power level) spectra are presented in figure 8(a) and (b). The spectra are similar in character to the peak angle SPL spectra with the exception that the differences between the baseline levels and the fully treated configuration levels are less on the basis of PWL.

The spectral noise reduction effectiveness as a function of liner length can be easily visualized in terms of the ΔPWL (power level attenuation) spectra. These spectra were calculated by subtracting the suppressed configuration PWL spectra from the hard baseline spectra. The attenuation spectra are shown in figure 9(a) and (b). In the frequency range from about 1000 to 4000 Hz these spectra look as expected. The peak attenuation occurs at 2500 and 2000 Hz, respectively, for 5100 and 6200 rpm speeds, and increasing the length of treated surface produces an orderly increase of attenuation. However, outside of this 1000 to 4000 Hz frequency range the attenuations become negative, with the amount depending on the lining configuration. The same type of result has been observed before in references 1 and 9. A negative attenuation really is an apparent noise generation over the baseline noise level. Therefore, the liner appears to be causing extra noise generation at both ends of the frequency spectrum. Below 1000 Hz there is no consistent pattern of this effect. Above 4000 Hz there is a consistent pattern; the shortest length appears to generate the most noise.

Previously we observed the smallest treatment addition resulted in a large reduction of MPT's. Treatment location effect was investigated. The effect of the shortest soft length addition (16.2%) is compared when it is located both at the fan face and also located at the inlet position most forward of the fan. The spectral noise reduction effectiveness as a function of position, in terms of ΔPWL (power level attenuation) spectra is shown in figures 10(a) and (b). The MPT noise reduction was somewhat greater when the treatment was located forward of the fan. Treatment location made little effect on blade passing tone reduction.

Normally, the MPT's form from non-linear propagation effects, shock waves, etc. with a consequent degeneration of energy from the blade passage tone into the MPT's. Since the MPT damping was equal or greater for forward placed treatment compared to treatment next to the fan face (fig. 19(b)), it would seem that the larger MPT noise damping rate is associated with some characteristic of this noise itself rather than MPT formation interference by treatment as has been suggested. If interference with MPT generation were involved in large damping, then one would have expected the larger damping rate to occur when the liner was next to the fan face.

Regarding the apparent noise generation observed, we suspect there may be tradeoffs between extra noise production and noise absorption as the amount of active liner changed. It seems unreasonable that the presence of the active liner treatment would cause extra noise generation at both ends of the frequency spectrum. An important observation is, in spite of the apparent noise generation, significant net attenuation occurred in the middle of the frequency spectrum to reduce the perceived noise levels as shown in figure 6.

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A reasonable question to ask is "How well did the liner perform relative to expectations?" This question can presently be answered only indirectly, the reason being that the prediction of the liner performance depends strongly on the duct modes, which are unknown. On this basis, the measured peak attenuations are plotted in figure 11 on a chart of predicted performances for optimized liners having single mode inputs[3]. Included on figure 11 is the predicted performance curve for the lowest order mode (zero lobe number) incident on an optimized liner. This particular curve has been used in the past to argue that open inlet noise suppressors would be inadequate to achieve needed large noise reductions. The present measured performance was significantly better than this lowest order mode prediction. The same observation has been made on earlier test results,[2]. Caution is required in interpreting figure 11. No inference can be made on the duct modes in this machine from the position of the data points, because in actual fact several modes are present in the duct and there is no knowledge that the present liner is anywhere near an optimum impedance. Furthermore, each mode present has its unique optimum impedance. Recall that the predicted curves in figure 11 are for a single mode present.

It is of interest to know how the liner performs as a function of length. This is shown graphically on figures 12 and 13 by selected cross plotting results from figures 6 through 9. Maximum PNL attenuations are shown in figure 12, while the PNL attenuation that occurs at the angle of maximum PNL is shown in figure 13. The shapes of the curves are similar in figure 12 and 13, although the PNL suppressions are greater in figure 13. This point was made in connection with the discussion of figure 6. The faired curve is essentially linear with length at 5100 rpm, while the curve rises rapidly then levels off at 6200 rpm. This behavior (at 6200 rpm) tends to substantiate the idea that the short sections of liner work well in reducing higher order modes; and that once these modes are reduced, the remaining lower order modes damp more slowly. This behavior (at 6200 rpm) is also associated with the possibility that MPT's damp faster as previously discussed. Examination of ΔSPL and ΔPWL as functions of length also support these ideas. Figures 14 and 15 present the ΔSPL and ΔPWL's versus length for certain selected 1/3-octave frequency bands near the peak of the attenuation spectra. In general, the behavior is similar to that of the ΔPNL versus length. Nearly all the curves begin to level off as length increases. The attenuation at 2000 Hz at 6200 rpm is chiefly that of MPT's which damp rapidly with a short length of liner, as observed earlier. In addition, the values of ΔPWL are generally less than the values of ΔSPL.

Summing up, there is a shift forward of the angle of peak PNL as the amount of lining increases. Also, the rate of attenuation per unit length decreases as the length increases. A possible explanation for these observations is that the far field radiation pattern may be initially controlled by higher order modes which damp easily, then become dominated by the lower order modes as the amount of active lining is increased. Finally, there was an apparent noise generation problem at low and high frequencies, but this problem does not prevent the liner from reducing the perceived noise level of the engine.

Inlet Striping Test Results

A series of tests were performed with longitudinal stripes formed by alternating active treatment liner and taped liner. These stripe tests involved two different configurations, both having active areas equal to 20% of the total active area of the fully treated open inlet. The first configuration had 55 narrow active strips, 1.27 cm (0.5 in.) wide. The other configuration had 12 wider active stripes, 5.95 cm (2.3 in.) wide.

Figure 16(a) and (b) display PWL attenuation spectra for the fan at 5100 and 6200 rpm. Again, extra noise generation at the low and high frequencies was exhibited by the striped configuration similar to that observed in the open inlet test results. Over most of the spectra the narrow 1.27 cm (0.5 in.) stripes gave larger attenuations than did the wide 5.95 cm (2.3 in.) stripes. The attenuation results for the two different stripe cases are generally similar in shape to the results from the fully treated open inlet. Even with less attenuation, the values for the stripe treatment are significant compared to the fully treated open inlet. These observations indicate that 20% treatment, in a longitudinal stripe configuration, approaches the effectiveness of 100% fully treated open inlet. Striping may represent a weight-saving concept for reducing engine noise if the noise reduction requirements are not too large.

Longitudinal striped treatment may be practical if integrated with structural longerons to achieve reasonable attenuations with small areas of treatment. Treated longerons could provide a weight advantage over full treatment.

Ring Insertion Results

One means of achieving greater noise reductions other than discussed above for the fully treated open inlet is to insert acoustically treated rings. Such a step however, carries with it aerodynamic and weight penalties. It was, therefore, desired to establish the noise reduction behavior as a function of the number of rings in place, with the hope that this number could be minimized. This section presents test results from three different configurations involving the insertion of various rings, as shown in figure 4 along with the three-ring configuration. Also included in figure 4 are the total areas active, relative to the three-ring design case. For all of these configurations, the duct wall was also acoustically active.

In figure 17 the sideline PNL directionality patterns are shown for the four ring insertion cases and compared with the baseline no-ring hard PNL pattern. Also included for comparison in the remaining figures are the results from the open inlet suppressor. In general, the noise reductions for the open inlet are less than for the ringed inlets. All of the ring results exhibit large noise reductions. Surprisingly, the single ring configuration results are nearly as good as the three ring results. At 6200 rpm, figure 17(b), it is puzzling that the three ring inlet has higher PNL's and removed less noise than the one and two ring inlets at some angles. The explanation for this behavior is not apparent, and examination of the SPL and PWL spectra also leaves the explanation in doubt.

4

The SPL spectra at 50.1° and 30.5 m (100 ft) radius are shown in figure 18 for the two speeds. The noise reductions from the baseline spectra are quite large for all configurations in the range from about 1 to 8 kHz. From looking at the 6200 rpm sound pressure level (figure 18(b)), the noise at 1 kHz is reduced more by the one and two outer ring configurations than it is by the three ring inlet or the single intermediate ring. This may be one of the factors contributing to the three ring inlet having higher PNL's than the one or two ring inlets at the 50.1° angle. Further comments about the spectral noise reductions will be made after the presentation of PWL reduction spectra since such discussions apply equally well there.

Figure 19 presents the PWL reduction spectra for the various ringed configurations and the no-ring configuration at 5100 and 6200 rpm. These spectra are generally similar in shape; as expected, the three ring inlet provides the largest attenuation and the two ring inlet is next best. The ring inlets, in general, are better suppressors at 6200 rpm than at 5100 rpm. The three (3) ring inlet functioned well at both speeds while the other ring suppressors were approximately 60% as effective at 5100 rpm. The effectiveness reduction is probably due to the deviation of the treatment operation from the tuned design operating conditions. It was unexpected, however, that the two different single ring configurations would perform so similarly. Apparently several competing effects combine to produce this result. In the case of the single outer ring (figure 4(b)) there are two parallel sound passages. Because the outer passage has a small passage height, it would be expected to perform quite well. That is, its dimensionless frequency parameter is low, while its length-to-height ratio is high. The inner passage is quite a large cylindrical duct which would not be expected to perform so well and which would therefore represent a noise leak. See reference 1 for further details of parallel acoustic passage performance. With the single intermediate ring in place, figure 4(c), the outer passage was larger and should perform poorer than the outer passage discussed above, while the inner passage is smaller and should perform better than the inner passage discussed above. With the possibility of spinning modes present, these effects become very complex. It is apparent that approximately compensating adjustments have occurred in going from one single ring inlet to the other.

From these results, the conclusion can be drawn that accepting slight compromises in the required attenuation can permit the use of fewer rings in the inlet. The weight and performance advantages to be gained could justify such a compromise.

Summary of Results

The TF-34 engine inlet acoustic liner performed better in off-design configurations than might have been expected from plane wave or least attenuated mode propagation analyses. This observation is tentatively attributed to the likelihood of complex modal patterns propagating out of the inlet. Some specific observations were as follows:
1. The open inlet (no-ring) acoustic liner provided noise reductions which were much larger than expected. Nevertheless, these reductions were not as large as those from the three ring inlet.

The conclusion is that, with some sacrifice of acoustic performance, considerable liner simplification can be achieved.
2. Variations of noise reduction parameters (PNL, SPL, PWL) were generally not linear with liner length in the open inlet. The initial length was generally more noise-reduction effective than an equal added length. This effect is likely due to modal effects.
3. Longitudinal striping of acoustic treatment in open inlets may be a viable means of reducing liner installation weights without too badly degrading the acoustic performance, for cases where modest noise reductions are required.
4. Removal of inner rings in the three ring design liner did not degrade the performance as much as expected. Apparently this effect may be due to spinning modes in the inner cylindrical passage.

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TABLE 1. - TF-34 DESIGN AND PERFORMANCE

(a) Design parameters

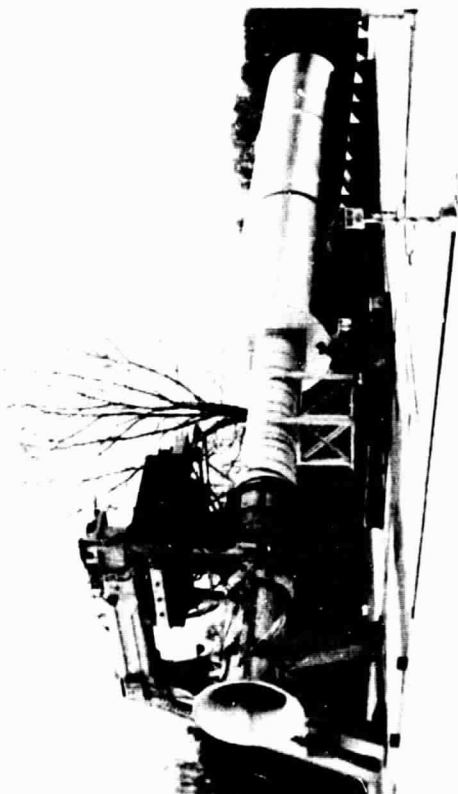|	
Fan diameter	1.12 m (44 in.)
Fan hub diameter	0.478 m (18.8 in.)
Number fan rotor blades	28
Number fan stator vanes	44

(b) Measured sea level static standard day performance

	Rotative speed, rpm,	Thrust N, (lb)	Fan pressure ratio,	Weight flow kg/sec, (lb/sec)	Bypass ratio,	Fan tip speed m/sec, (ft/sec)
Unsuppressed single exhaust	6800 max power	40 900 (9200)	1.480	151 (332)	6.7	398 (1307)
Suppressed 3-ring engine as installed	6930 max power	35 700 (8040)	1.473	149 (328)	6.71	406 (1332)
	6200	27 500 (6180)	1.364	134 (295)	7.07	363 (1191)
	5100	16 700 (3760)	1.224	109 (240)	7.40	299 (980)
Suppressed no-ring engine as installed	6930 max power	36 700 (8280)	1.473	152 (335)	6.79	406 (1332)
	6200	28 300 (6370)	1.364	137 (302)	7.16	363 (1191)
	5100	17 000 (3830	1.225	110 (242)	7.40	299 (980)

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ROTOR
STATOR

DIMENSIONS, m (IN.)

1.66 (65.1)
0.33 (12.6)
0.99 (39)
1.12 DIAM. (44)
0.825 (21)
0.534 (21)
0.241 (9.5) DIAM.

ACOUSTIC TREATMENT

PERFORATED FACE SHEET -
0.05 CM (0.02 IN.) THICK; 0.127 CM (0.05 IN.)
HOLE DIAMETER; 6.8% OPEN AREA
HONEYCOMB - 12 CM (0.48 IN.) DEEP
SPLITTER THICKNESS - 3.2 CM (1.25 IN.)

PART	TOTAL TREATED LENGTH, m (IN.)	PASSAGE HEIGHT, m (IN.)
OUTER WALL	1.33 (52.5)	0.114 (4.5)
OUTER RING	.71 (28)	.114 (4.5)
MIDDLE RING	.71 (28)	.114 (4.5)
INNER RING	.57 (22.5)	.241 (9.5)

Figure 2 - Three ring engine inlet design. (Total treated area is 12 m² (129 ft²).)

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Figure 1. - Engine on test stand with aft muffler in place.

(a) TWO-OUTER-RING CONFIGURATION. 92% OF DESIGN AREA ACTIVE.

(b) SINGLE-OUTER-RING CONFIGURATION. 71% OF DESIGN AREA ACTIVE.

(c) SINGLE-INTERMEDIATE-RING CONFIGURATION. 60% OF DESIGN AREA ACTIVE.

Figure 4. - Engine inlet configurations with various ring arrangements.

ROTOR
STATOR

1.66 m (65.1 IN.)

TREATED LENGTH VARIATION

ACTIVE = 5.84 m² AREA

100%
58.1% ACTIVE
37.4% ACT.
16.2% ACTIVE

16.2% ACTIVE
FORWARD POSITION

(a) NO RING OR OPEN INLET TREATMENT.

55 SEGMENTS OF 5 CM (2.0 IN.)   12 SEGMENTS OF 23.4 CM (9.2 IN.)
HARD TAPE WITH 1.27 CM (0.5 IN.) HARD TAPE WITH 5.84 CM (2.3 IN.)
SOFT SPACES   SOFT SPACES

(b) OPEN INLET 20% STRIP TREATMENT.

Figure 3. - Engine open inlet.

HARD BASELINE
○ 16.2% ACTIVE TREATMENT
□ 37.4% ACTIVE TREATMENT
◇ 58.1% ACTIVE TREATMENT
△ 100% ACTIVE TREATMENT
△ (100% TREATMENT = 1.33 m (52.5 IN.))

(a) 5100 RPM.

(b) 6200 RPM.

PERCEIVED NOISE LEVEL, PNdB

ANGLE FROM INLET DIRECTION, DEG

Figure 6. - Open inlet treated length effect angular distribution of perceived noise level at 152.5 m (500 ft) sideline.

ENGINE INLET PLANE STATION

MICROPHONE ARC CENTER STATION

7 METERS (22.9 FT)

10° TYPICAL

CORRECTED RADIUS, 30.5 m (100 FT)

30.5 m (100 FT) MICROPHONE ARC

30.5 m (100 FT) COMPUTER CORRECTED MICROPHONE ARC

MICROPHONE ANGLE CORRECTION, DEG			
OLD°	NEW°	OLD°	NEW°
0	0	90	102.9
10	12.9	100	112.2
20	25.7	110	121.3
30	38.1	120	130.1
40	50.1	130	138.7
50	61.6	140	147.1
60	72.6	150	155.5
70	83.1	160	163.7
80	90		

Figure 5. - Engine test site microphone layout with computer corrected overlay.

Figure 7. - Open inlet treated length effect sound pressure level spectra at baseline peak PNL angle.
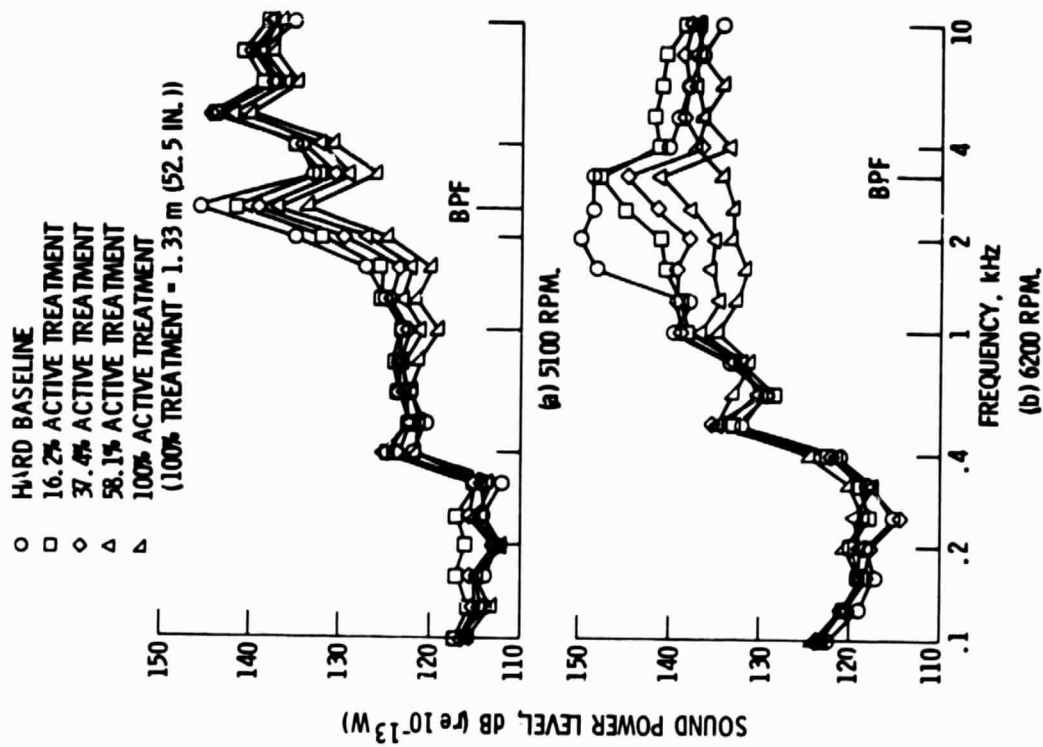
Figure 8. - Open inlet treated length effect inlet hemisphere power spectra.

Figure 9. - Open inlet treated length effect sound power level attenuation spectra.
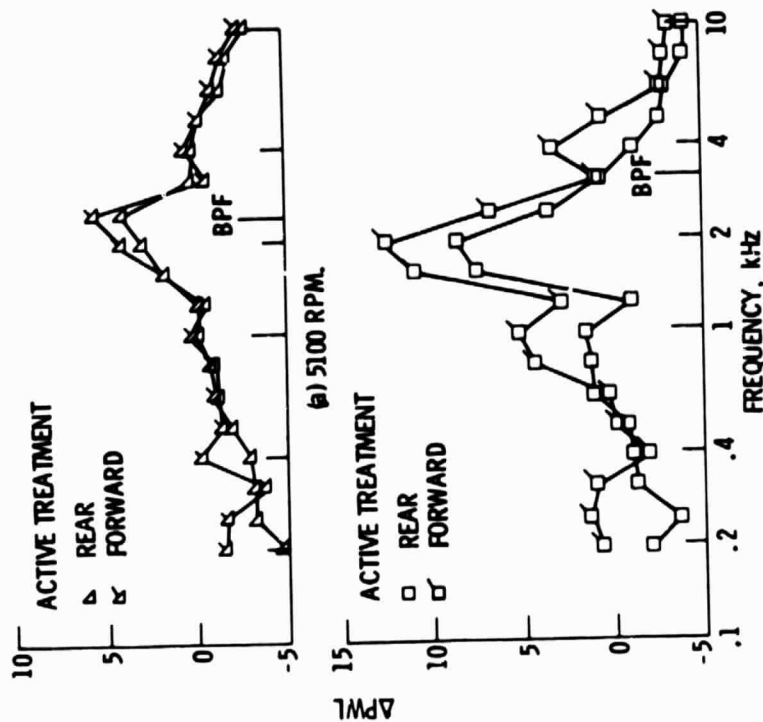
Figure 10. - Open inlet treated length effect sound power level attenuation spectra 16.2% treatment location comparison.
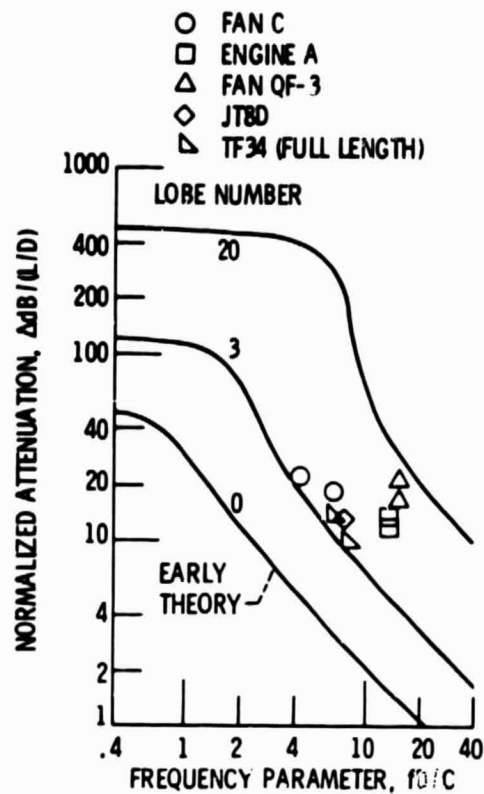
F-8693

FAN C
ENGINE A
FAN QF-3
JTBD
TF34 (FULL LENGTH)

Figure 11. - Measured peak atten-
uation compared to theoretical
(different spinning lobe num-
bers) for open inlets.
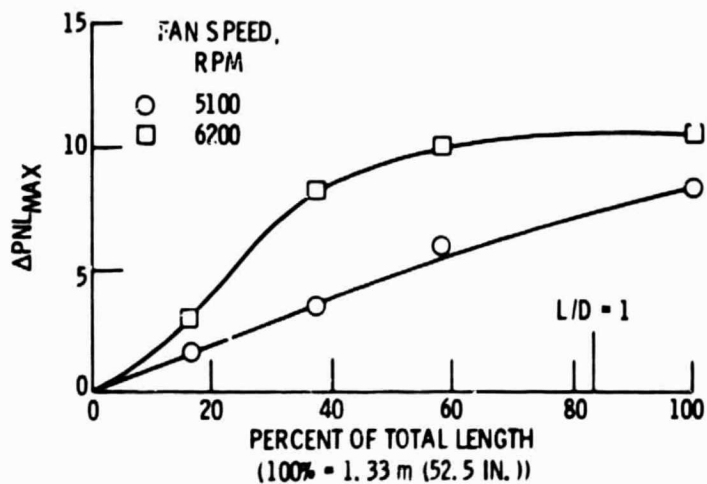
Figure 12. - Open inlet treated length effect reduction of max-
imum sideline perceived noise level (152.5 m (500 ft).
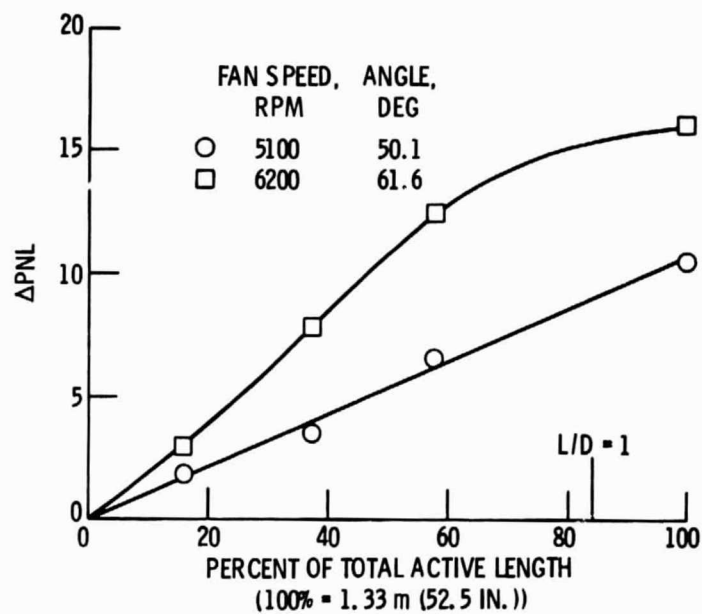
Figure 13. - Open inlet treated length effect reduction of per-
ceived noise level at fixed angle on a 152.5 m (500 ft) side-
line.
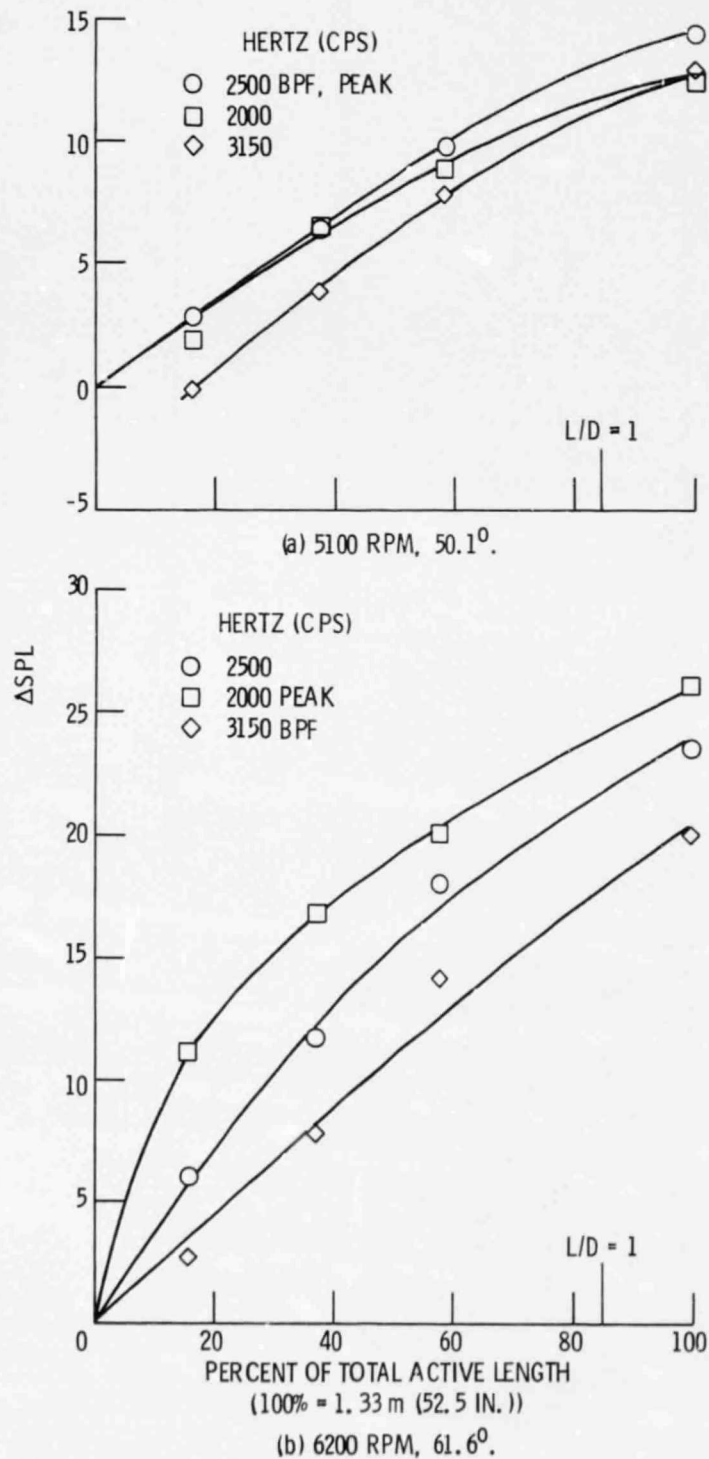
Figure 14. - Open inlet treated length effect reduction of sound pressure level at selected 1/3 octave bands of a 30.5 m (100 ft) sideline.
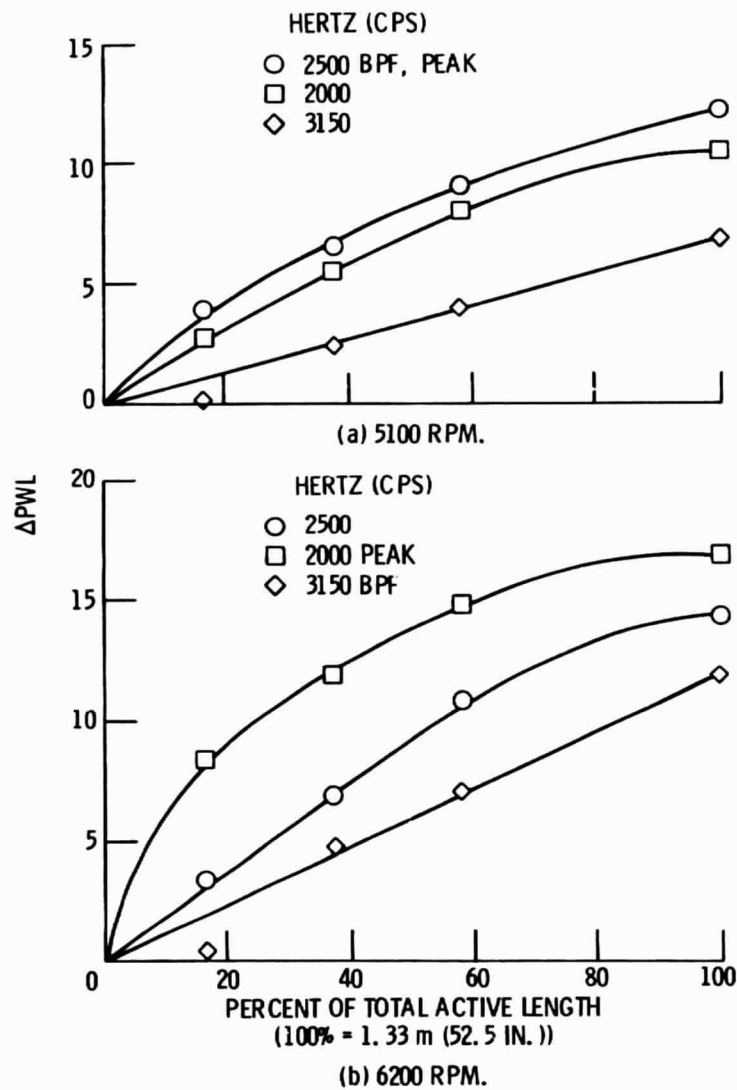
Figure 15. - Open inlet treated length effect reduction of sound power level at selected 1/3 octave bands.
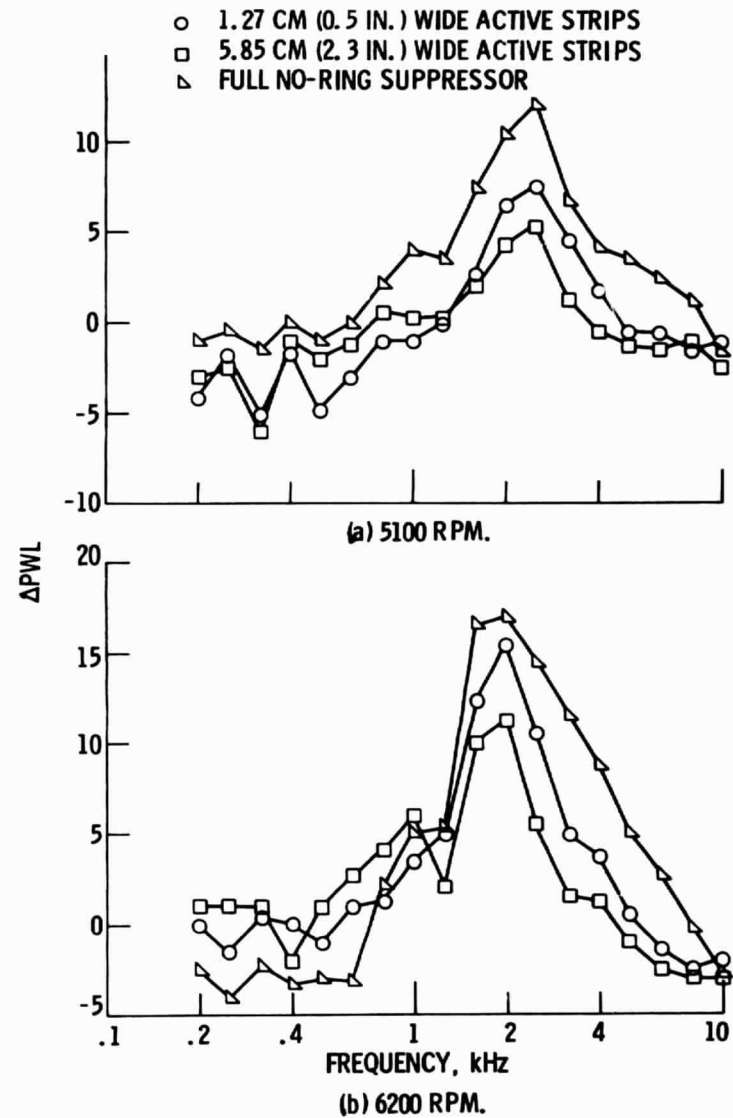
Figure 16. - Open inlet suppressor attenuation spectra for axial tape striping (20% of total area active).
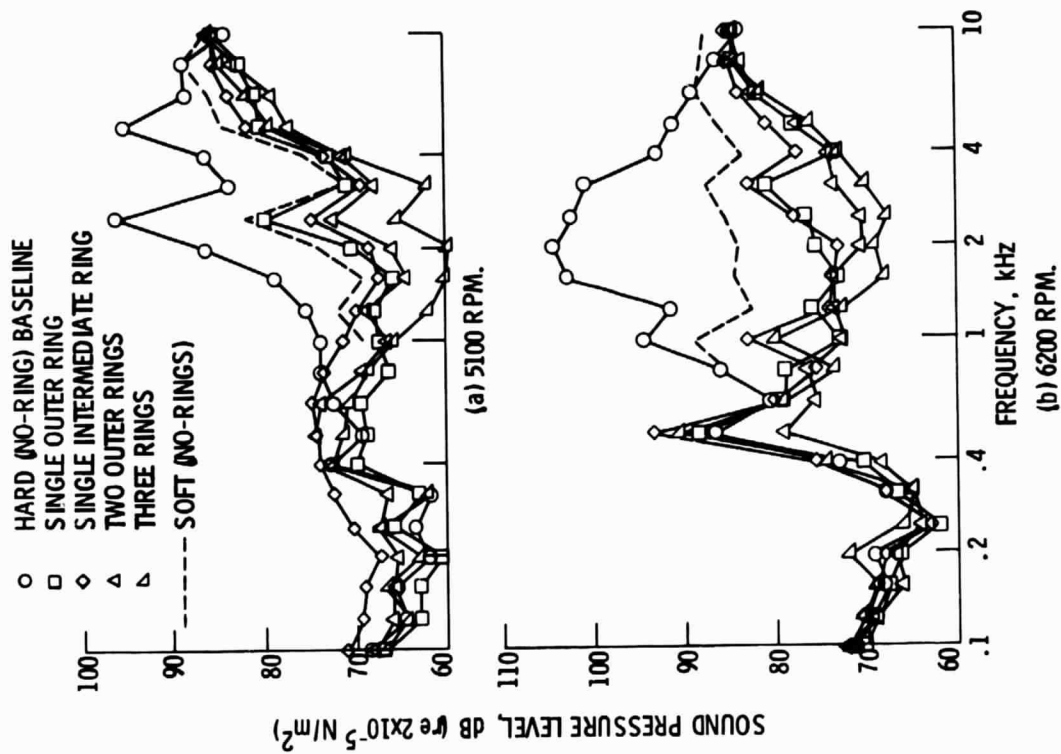
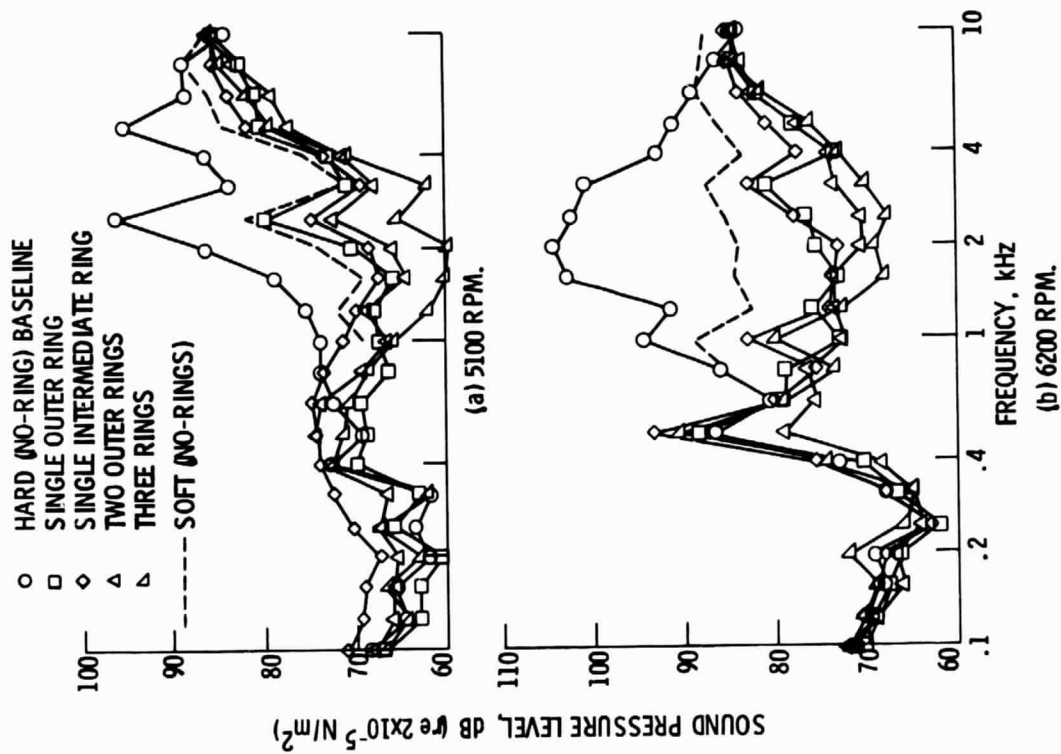Figure 17. – Ring effect on perceived noise level.

HARD BASELINE
SINGLE OUTER
SINGLE INTERMEDIATE
TWO OUTER
THREE RINGS
NO-RING

(a) 5100 RPM.

(b) 6200 RPM.

PERCEIVED NOISE LEVEL, PNdB

ANGLE FROM INLET, DEG

HARD (NO-RING) BASELINE
SINGLE OUTER RING
SINGLE INTERMEDIATE RING
TWO OUTER RINGS
THREE RINGS
SOFT (NO-RINGS)

(a) 5100 RPM.

(b) 6200 RPM.

FREQUENCY, kHz

SOUND PRESSURE LEVEL, dB (re 2x10^{-5} N/m^2)

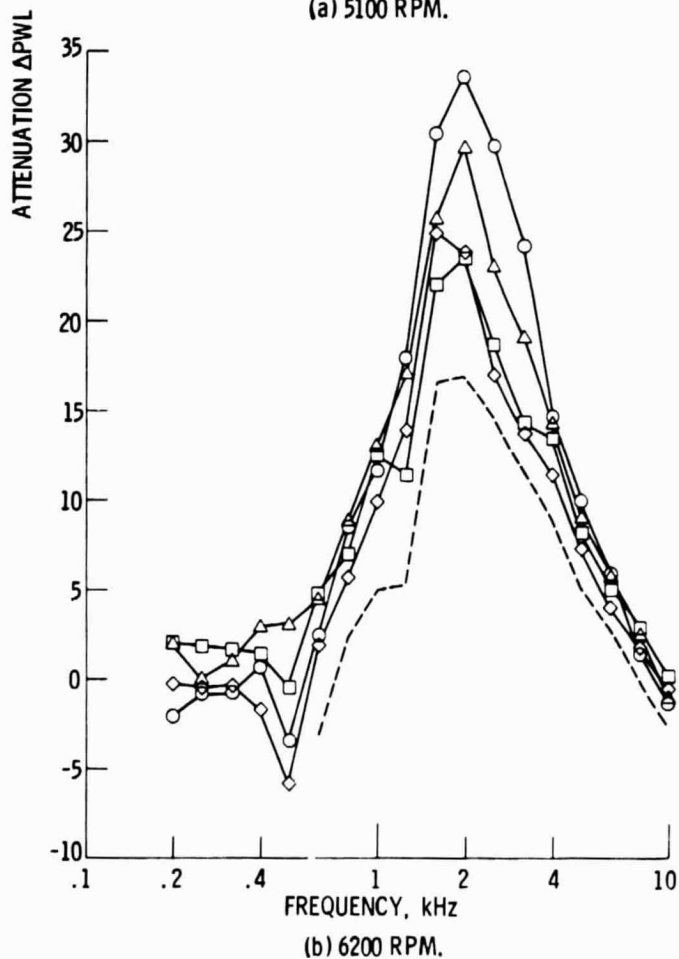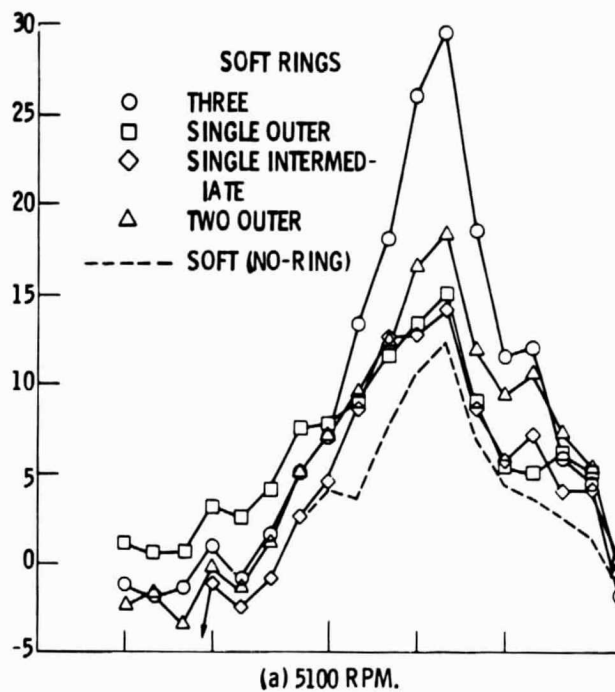Figure 18. – Ring effect on sound pressure level spectra for 50.1° on 30.5 m (100 ft) radius.

Figure 19. - Ring effect on power level attenuation
spectrum